The smallest measurements ever yet made, viz. 1/2,000,000 millimetre, were in connection with the movements of a telephone diaphragm. The problem was to find what movement of the diaphragm produces a sound which is only just audible.

This is done as follows:—Place a telephone to the ear and pass through it a steady current. On stopping the current a sharp sound is heard in the telephone. Alter the strength of the current until when it is stopped the sound can only just be heard. Observe on a galvanometer the strength of that current (C). Next put the telephone in the electric micrometer in place of the rod R, pass the current (C), and measure the movement of the diaphragm in the usual way. This movement then produces a sound in the telephone which is just audible.

Another use of the instrument is to measure the sparking distance between two surfaces, the potential difference of which is known. The surfaces used are P, Q in the figure. Suppose the potential difference between these surfaces is very small, say 1/1000 volt. Find the contact position as above, and draw P away from Q. Now make the potential difference between P and Q equal to 1 volt. On making P approach Q the contact position has changed by an amount D. Thus the sparking distance for 1 volt is D (supposing the spark distance for 1/1000 volt is negligible). This is found to be about 1/100,000 mm.

In problems on the constitution and molecular properties of matter there are obvious possibilities before this apparatus, for by it we can bring two surfaces of any hard metal to molecular distance (or less) from one another, and keep them there while any desired physical change is produced in the surfaces or in the medium surrounding them.

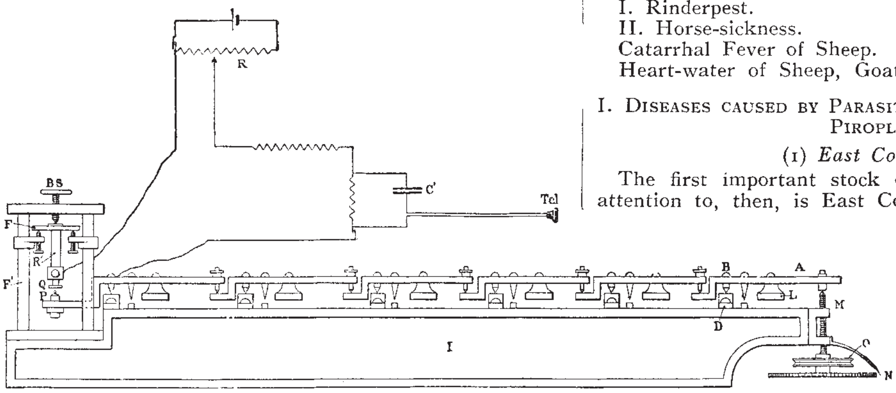

FIG. 1.—The Electric Micrometer.

THE BRITISH ASSOCIATION.

SECTION I.

PHYSIOLOGY.

OPENING ADDRESS BY COLONEL D. BRUCE, M.B., F.R.S., C.B., PRESIDENT OF THE SECTION.

The Advance in our Knowledge of the Causation and Methods of Prevention of Stock Diseases in South Africa during the last ten years.

TEN years ago, when I first came to South Africa, I was led to take an interest in the various great stock diseases which do so much damage and so retard the progress of South Africa as a stock-raising country. I thought, therefore, that a good subject for my address, in the centre of the foremost stock-raising Colony of South Africa, would be a review of the work done in advancing our knowledge, during the last ten years, of the causation and methods of prevention of stock diseases in South Africa. South Africa is particularly rich in animal diseases, every species of domestic animal seemingly having one or more specially adapted for its destruction. Now it is evident that, in an address of this kind, it will be impossible to take up every stock disease, but I think you will agree with me that those shown on this table are among the most important:—

East Coast Fever; ordinary Redwater or Texas Fever; Biliary Fever of Horses; Malignant Jaundice of Dogs; Nagana or Tsetse-fly Disease; Trypanosomiasis of Cattle; Rinderpest; Horse-sickness; Catarrhal Fever in Sheep; Heart-water of Sheep, Goats, and Cattle.

Now we may group these diseases in various ways; for example, as below, where they are divided into two main divisions: *A* division, in which the parasite is known; and *B* division, in which the parasite is unknown.

A. Parasite known.

I. Diseases caused by parasites belonging to the genus Piroplasma:—

(1) East Coast Fever (Koch), *P. parvum.*

(2) Redwater or Texas Fever, *P. bigeminum* (Theiler).

(3) Biliary Fever of Horses, Mules, and Donkeys, *P. equi.*

(4) Malignant Jaundice of Dogs, *P. canis.*

II. Diseases caused by parasites belonging to the genus Trypanosoma:—

(1) Nagana or Tsetse-fly Disease, *T. brucei* (Bradford and Plimmer).

(2) Trypanosomiasis of Cattle, *T. theileri* (Bruce).

B. Parasite unknown.

I. Rinderpest.

II. Horse-sickness.

Catarrhal Fever of Sheep.

Heart-water of Sheep, Goats and Cattle.

I. DISEASES CAUSED BY PARASITES BELONGING TO THE GENUS PIROPLASMA.

(1) *East Coast Fever.*

The first important stock disease I would direct your attention to, then, is East Coast Fever. This name was given to it by Prof. Robert Koch, of Berlin. In the Transvaal the disease is usually called Rhodesian Redwater. This term is not a good one, since the disease is not restricted to Rhodesia, nor did it arise there, nor is this a disease similar to the ordinary Redwater. Ten years ago, East Coast Fever was unknown in the Transvaal. The first known outbreak occurred only some three and a half years ago, when it broke out at Koomati and Neilspruit, in the Barberton district, and in the east of the Colony. The disease had broken out some time previously in Rhodesia, and the outbreaks in both Colonies were due to infection from Portuguese territory. Although this disease has only been introduced to the country during the last few years, it has already produced an enormous amount of damage among stock, and is probably the most dangerous disease that the people of the Transvaal have to cope with at the present time, and for some years to come.

In the Annual Report of the Transvaal Department of Agriculture there is a most excellent report by Mr. Stockman, the then Principal Veterinary Surgeon, on the work of the veterinary division for the year 1903–1904. A large part of this report is given up to East Coast Fever, and I must here express my indebtedness to Mr. Stockman for much of the following account of this disease. In the same Annual Report there is also an account by Dr. Theiler, the Veterinary Bacteriologist, of the experimental work. Messrs. Stockman and Theiler evidently worked together, and I must congratulate them on the immense amount of good, useful work done by them, and I would also congratulate the Government on having had the services of two such accomplished and energetic gentlemen during the late troublesome times. Unfortunately for the Transvaal, Mr. Stockman has accepted the post of Veterinary Adviser to the Board of Agriculture in England, but I have no doubt his successor, Mr. Gray, from Rhodesia, will continue the good work begun by him.

East Coast Fever was first studied by Prof. Koch at Dar-el-Salaam, in German East Africa, and he at first mistook it for ordinary Redwater. It seems to occur as an endemic disease along a great part of the East Coast of Africa, but appears to be restricted to a narrow belt along this coast-line. The cattle inhabiting this region have become immune to the disease, and are, therefore, not affected by it. Cattle passing through the Coast district to the interior, or brought to the Coast district from the interior, are apt to take the disease and die. It was by the importation of cattle, therefore, which had passed through the dangerous Coast district that the disease was introduced into Rhodesia and into the Transvaal. On this map which I throw on the screen I have marked out the probable endemic area of this disease, and in the next slide the present distribution of the disease in the Transvaal is also marked out.

Nature of the Disease.—This disease only attacks cattle, but in them is an exceedingly fatal malady: in every hundred cattle attacked only about five recover from the disease. The duration of the disease after the first symptoms have occurred is about ten days.

The cause of the disease is a minute blood parasite called the *Piroplasma parvum* (Theiler). This parasite lives in the interior of the red blood corpuscles.

I now throw on the screen a representation of the blood from a case of Rhodesian Redwater, magnified about a thousand times, showing these small piroplasmata in the interior of the red blood corpuscles. As in the case of so many of these blood diseases, the parasite causing it is carried from the sick to the healthy by means of a blood-sucking parasite. In this particular disease the tick which most commonly transfers the poison or living parasite from one animal to another is known as the "brown tick," *Rhipicephalus appendiculatus*. Koch supposed that the common "blue tick" was the agent. The credit belongs to Dr. Lounsbury and Dr. Theiler of having shown that it is chiefly the "brown tick" which acts as carrier; but Theiler has proved that *R. simus* is also able to transmit the disease. Without the intervention of a tick, so far as we know at present, it is quite impossible that the parasite of this disease can be transferred from one animal to another. For example, if we take a quantity of blood containing enormous numbers of these piroplasmata, and inject it into the blood circulation of a healthy animal, the latter does not take the disease. In the same way, if cattle affected by East Coast Fever are placed among healthy cattle in a part of the country where none of these "brown ticks" are found, the disease does not spread. It is evident, therefore, that some metamorphosis of the parasite must take place in the interior of the tick, and this new form of the parasite is introduced by the tick into a healthy animal, and so produces the disease. In this particular disease the virus or infective agent is not transmitted through the egg of the tick, as is the case in some of these parasitic diseases, but only in the intermediate stages of the tick's development; that is to say, the larva which emerges from the egg of the tick is incapable of giving the disease. What happens is this. The larva creeps on to an infected animal and sucks some of its blood. It then drops off, lies among the roots of the grass, and passes through its first moult. The nympha, which is the name given to the creature after its first moult, is capable of transferring the disease to a healthy animal: that is to say, if it crawls on to a healthy animal and sucks blood from it, it at the same time infects this healthy animal with the germ of E.C.F. In the same way, if a nympha sucks infected blood from a sick animal, it is able, after it has moulted into the adult stage or imago, again to give rise to the disease if placed, or if it crawls, upon a healthy animal.

The Life-history of the Brown Tick.—I throw on the screen a slide representing the four stages of the life-history of the brown tick: The egg, the larva, the nympha, and the adult or imago. The eggs are laid on the surface of the ground by the adult females, which deposit several thousands at a time; and these hatch out naturally, if the weather is warm and damp, in twenty-eight days. But this period of incubation of the eggs may vary very greatly owing to differences in temperature. Immediately after the larva is born it crawls to the summit of a blade of grass or grass stem, and there awaits the passage of some animal. If an ox passes by and grazes on the grass, the tick at once crawls on to the animal, and, having secured a favourable position, starts to suck the ox's blood. It remains on the ox for some three or more days, when, having filled itself with blood, it drops off and lies among the grass. The first moult, under favourable conditions, takes twenty-one days, when the nympha emerges. In the same way the nympha crawls on to an animal and fills itself with blood. As a nympha it also remains on the animal for about three or four days. It again drops off into the grass, and at the end of eighteen days emerges from its second moult as the perfect adult male or female. The males and females again crawl on to an ox, where they mate. After this the female tick ingests a large quantity of blood, which is meant for the nourishment of the eggs, and again drops off, sometimes as early as the fourth day, into the surrounding grass. After about six days she lays her eggs in the ground, and the cycle begins again.

These ticks are very hardy, and in the intermediate stages can resist starvation for long periods, so that a larva or nympha or adult tick may remain perched at the end of a blade of grass for some months without finding an opportunity of transferring itself to a suitable animal. On this account it comes about that even if all infected cattle are removed from a field the ticks in that field will remain capable of transferring the infection to any healthy cattle which may be allowed into this field for a period of about a year. At the end of a year or fifteen months, however, the infective ticks are all dead, and clean cattle may be allowed into the field without any risk. If one takes these facts into consideration it will be seen that a single ox may spread this disease for a distance of some 200 miles, if trekking through the country at the average rate of ten miles a day. For example, an ox is infected by a tick; for fourteen days the animal remains apparently perfectly well; it has no signs of disease, nor has it any fever. It is capable of doing its ten miles' trek a day. At the end of fourteen days the temperature begins to rise, and the animal begins to sicken with the disease, but for the next six days the ox is, as a rule, able to do its ordinary day's march. During most of this time the brown ticks have been crawling on to this ox, becoming infected, and dropping off every three or four days. It can readily, therefore, be seen how much mischief a single infected animal can do to a country between the time of its being infected by the tick and its death some twenty-four days later. As a matter of experience, however, the disease has never been found to make a jump in this way of more than fifty or sixty miles, as, of course, it is very rare that a transport carrier will take his oxen more than that distance during the twenty days.

At the present time it may be said that there are about 500 infected farms in the Transvaal. During last year some 15,000 cattle have died of the disease, and in the affected districts it may be said that there are still some 30,000 cattle alive. When one considers the value of the cattle dead of this disease, which may be said to be about 200,000*l.*, it is evident that money spent on the scientific investigation of the causes and prevention of stock diseases is money well spent. I am informed that all the South African Governments are cutting down their estimates this year, and are inclined to reduce their veterinary staffs and the amounts devoted to research regarding animal diseases. Ladies and gentlemen, if this is so, I have no hesitation in saying that this is the maddest sort of economy and the shortest-sighted of policies.

Methods of combating the Disease.—During the last three years an immense amount of work has been done in the elucidation of this disease—how the animals are infected, how the poison is spread from the sick to the healthy, and so on. In 1903 Prof. Koch was asked by the South African Colonies to study this disease, in order to try to find some method of artificial inoculation or some other means of prevention. He did his work in Rhodesia, and especially directed his energies towards discovering some method of preventive inoculation. At first it was thought that he would be successful in this quest, as in his second report he announced that he had succeeded in producing a modified form of the disease by direct inoculation with the blood of sick and recovered animals. As you are all aware, the only method of conferring a useful immunity upon an animal is to make it pass through an attack of the disease itself, so modified as not to give rise to above a few deaths in every hundred inoculated. This is the method that has been employed in such diseases as Rinderpest, Anthrax, Pleuro-pneumonia, and many other diseases. The great difficulty in this disease in finding a method of preventive inoculation is the fact that the blood of an affected animal does not give rise to the disease in a healthy one when directly transferred under the skin of the latter. It is only after its passage through the body of the tick that the parasite is able to give rise to the disease in a healthy animal. It is evidently, on the face of it, difficult to so modify the parasite during its sojourn in the tick's body as to reduce its virulence to a sufficient degree.

Prof. Koch in his third and fourth reports recommended that cattle should be immunised by weekly or fortnightly inoculations of blood from recovered animals, extending over a period of five months. Even though this method of Koch had given the desired result, viz. that it rendered the inoculated cattle immune to the disease, it is evident that the method itself can hardly be made a practicable one on a large scale in the field. The expense and trouble of inoculating cattle on twenty different occasions would be very great. It is apparent now that Prof. Koch fell into error through mixing up East Coast Fever with ordinary Redwater. His plan of preventive inoculation was, however, tried on a large scale in Rhodesia by Mr. Gray, now the P.V.S., Transvaal, and found to be useless. At present, therefore, we must look to some other means of preventing the disease and driving it out of the country than preventive inoculation.

Dipping.—Much can be done to prevent the spread of this disease by ordinary methods. For example: in the case of Texas Fever in Queensland dipping cattle in solutions of arsenic or paraffin, in order to destroy the ticks, has met with very fair success; but in the case of this disease we cannot expect to get as good results as in the case of Redwater. The species of tick which conveys Texas Fever remains on the same animal through all its moults, instead of falling to the ground between each different one. If it is not possible to spray or dip cattle oftener than once in ten or fifteen days, it is evident that ticks may crawl upon such animals, become infected, and drop off every three or four days, and so escape destruction by the dipping solution. At the same time every infected tick that is killed by spraying or dipping operations is a source of infection destroyed.

Fencing of Farms.—Again, the fencing of farms must also be useful in the same direction. As the ticks do not travel to any extent when they fall among the grass, it is evident that the cattle on a clean farm which is properly fenced will not become infected by this disease, although all the country round about should be infected. This fencing of farms and subdividing the farm itself into several portions is a most important factor in the prevention of contagious diseases amongst stock. It is, of course, impossible that this can be done at once, as the expense would be prohibitive.

Moving Cattle from Infected Pasture to Clean Pasture.—From a study of this disease and a study of the life-history of the tick it is evident that by a combination of dipping or spraying the cattle so as to destroy almost all the ticks, slaughtering the sick, and moving the apparently healthy on to clean veld—and repeating this, if necessary, a second or third time—it is obvious that by these means, if circumstances are favourable, an outbreak of this disease may be nipped in the bud without much loss to the stock.

Stamping out the Disease.—In May, 1904, an inter-Colonial Conference held at Cape Town resolved that the only effective method of eradicating East Coast Fever is to kill off all the cattle in the infected areas, and to leave such areas free of cattle for some eighteen months. By this means all the centres of infection would be destroyed, and at the end of eighteen months, as all the infected ticks would be dead, it is evident that the disease would be completely stamped out. There is no doubt that this drastic method would be the quickest and most complete one of getting rid of this extremely harassing disease. If compensation were given, it could be done at a cost of, say, a quarter of a million. The Government decided, however, that on account of the difficulty of carrying out such a drastic scheme another policy had to be considered. This policy provides for the fencing-in of infected farms, places, lands, or roads, on generous terms; the compulsory slaughter of stock with compensation in the case of isolated outbreaks; the removal of all oxen from infected or suspected farms; and, lastly, the stabling of milch cows in infected areas. It is quite evident that under this less drastic policy the final stamping-out of the disease will be a much slower process than if the more drastic scheme of compulsory slaughter of all cattle on infected areas had been carried out. The benefits, however, from the modified scheme are undoubted; and if carried out thoroughly and intelligently for a period of several years will probably result in the stamping-out of the disease.

Allow me to sum up in regard to the advance in our knowledge of this important stock disease during the last ten years. Ten years ago nothing was known. Now the causation of the disease has been made out very fully; the parasite that causes it is known; the ticks which carry the infection are known. Although no method of conferring immunity on healthy cattle has been found out, or any medicinal treatment discovered which will cure the sick animal, yet our knowledge of the life-history of the parasite and the ticks enables regulations to be framed which, if patiently carried out, must be crowned with success.

(2) *Redwater or Texas Fever.*

I may dismiss this disease in a few words. It is a most interesting disease and of great importance to stock farmers. It only affects cattle.

Geographical Distribution.—It is a disease found in almost every part of the world. It was first studied in North America; hence the name Texas Fever. To Kilborne and Smith is due the honour of elucidating the causation of this disease, and their work forms one of the most interesting chapters in the history of pathological science. They discovered that it was caused by the presence in the red blood corpuscles of a protozoal parasite closely related to the parasite found in E.C.F.—the *Piroplasma parvum.* This organism is called *Piroplasma bigeminum.* They further discovered that this parasite was conveyed from sick to healthy cattle by means of a tick. They also showed that the cattle born and bred in certain southern districts are immune to the disease, whereas cattle in the northern districts are susceptible. Hence, if southern cattle were driven into the northern district, they gave rise to a fatal disease among the northern cattle; and, *vice versâ,* if the susceptible northern cattle were driven into the southern district among the apparently healthy cattle of that district, they took Texas Fever and died.

Texas Fever was introduced about 1870, and is now endemic throughout most of South Africa. For many years the native cattle have been immune to the disease; that is to say, on account of being born and bred in a Texas Fever locality they had inherited a degree of resistance to the disease which enabled them to pass through an attack when they were young, and so they became immune. But there is one peculiarity about Texas Fever which does not occur in Rhodesian Tick Fever, and that is that the blood of an animal which has recovered from Texas Fever remains infective—the germs remain latent—and so the native cattle of South Africa, although apparently healthy, are capable of infecting imported susceptible cattle with this very fatal malady. This is what makes it so difficult to import prize stock into this country.

When the Boers visited Mooi River, at the beginning of the war, they found a prize short-horn carefully stabled in Mr. P. D. Simmon's farm. They killed most of his stock for food, but left this short-horn bull alive. When they left the farm they turned this bull into the nearest field, in order, of course, that it might procure food. They had much better have eaten it. It promptly took Texas Fever and died.

This disease, then, has become of secondary importance to South Africa in these days. The native cattle have become naturally immune, and the disease is only fatal to susceptible imported cattle. This, of course, discourages the importation of prize stock; but with the knowledge we possess it ought to be possible, by good stabling and prevention of contact with tick-infected cattle, to keep the prize stock alive for a reasonable time. The question of the feasibility of immunising the prize stock while calves in England might be considered.

In regard to methods of conferring immunity on susceptible cattle many have been tried, but none are absolutely free from risk.

We may sum up in regard to Redwater or Texas Fever by saying that our knowledge of its causation and methods of prevention is much the same as it was ten years ago. The work done by Smith and Kilborne on this disease was of such a brilliant nature, and was done so thoroughly, that little has been left for later workers to do.

(3) *Biliary Fever of Horses, Mules, and Donkeys.*

This is a disease of horses, mules and donkeys very similar to Redwater in cattle, and is caused by a closely allied parasite, the *Piroplasma equi,* discovered for the first time in South Africa by Bordet, Danysz, and Theiler, and named by Laveran of Paris.

It is similar to Redwater, in that animals which have recovered from the disease remain a source of infection during the remainder of their lives to susceptible animals. The native South African horse is, like the cattle, immune to the disease. It is also conveyed by a tick, which has been shown by Theiler to be the "red tick" (*Rhipicephalus evertsi*), the infection being taken in the nymphal and transferred in the adult stage. Theiler has also made the very important observation that if a horse is injected with blood from a donkey which has recovered from the disease, as a rule a mild form of the disease is produced, so that this opens up a method of immunising susceptible horses which may probably prove of practical value. Theiler has also made another curious discovery. This disease of horses was found to greatly complicate certain immunising experiments he was making against Horse-sickness. He found he was introducing the *Piroplasma equi* at the same time he injected Horse-sickness virus. But he found out that as the virus of Horse-sickness keeps its virulence for years, whilst the *Piroplasma equi* dies out in a short time, this danger could be avoided by keeping the Horse-sickness serum and virus for some time before using it.

(4) *Malignant Jaundice of Dogs.*

This disease is most important to sportsmen or to importers of valuable dogs, as most of these are attacked sooner or later by this disease, and most of them succumb. It is also caused by a species of Piroplasma (*Piroplasma canis*), and is spread by the dog tick (*Haemophysalis leachii*).

Like Redwater and Biliary Fever, the blood of dogs which have recovered remains infective.

The story of the tick infection is a curious one, and the credit of its discovery is due to Lounsbury. It is only in the adult stage that the tick is capable of producing the disease. It is therefore evident that the Piroplasma must remain latent in the egg, the larval and nymphal stages, and only attain activity in the adult stage.

According to Theiler there exists a peculiar phenomenon which may be made use of to confer immunity. The blood of a dog which has recovered from this disease and has been hyper-immunised is, as mentioned above, capable of giving rise to the disease in a susceptible dog. Now, if serum be obtained from this blood and a quantity added to a small amount of the blood, this infected blood loses its infectivity and no disease results.

II. DISEASES CAUSED BY PARASITES BELONGING TO THE GENUS TRYPANOSOMA.

(1) *Nagana or Tsetse-fly Disease.*

We now come to the second group of diseases. These are also caused by blood parasites belonging to the same class of living things as the Piroplasma, but which are free organisms, swimming in the fluid part of the blood, and not contained in the red blood corpuscles, as are the others.

The first of this group I would direct your attention to is that disease called *Nagana* or the *Tsetse-fly Disease.*

This fly renders thousands of square miles of Africa uninhabitable. No horses, cattle, or dogs can venture, even for a day, into the so-called "Fly Country." Now what was our knowledge of this disease ten years ago? At that time it was thought that the tsetse-fly killed animals by injecting a poison into them, in the same way as a snake kills its prey. Nothing was known as to the nature of this poison in 1894. In 1895, on account of serious losses among the native cattle in Zululand from this plague, the then Governor of Natal and Zululand, Sir Walter Hely-Hutchinson, started the investigation of this disease. The result of this investigation was the discovery that Tsetse-fly Disease was not caused by a simple poison elaborated by the fly, as formerly believed, but that the cause of the disease was a minute blood parasite which gained entrance to the blood of the animals. This parasite is known by the name Trypanosoma, which signifies a screw-like body.

Ten years ago two species only had attracted much attention—one living in the blood of healthy rats, discovered by Surgeon-Major Lewis in India; and the other, a trypanosome, found in the blood of horses and mules suffering from a disease known in India as "Surra." As the result of this investigation in Zululand, which lasted two years, it was proved that this trypanosome was undoubtedly the cause of the death of the horses and cattle struck by the fly, and that the tsetse-fly merely acted as a carrier of this blood parasite.

Here is a representation of the trypanosome of Nagana on the screen. These trypanosomes consist of a single cell; are sinuous, worm-like creatures, provided with a macronucleus and a micronucleus, a long terminal flagellum, and a narrow fin-like membrane continuous with the flagellum and running the whole length of the body. When alive they are extremely rapid in their movements, constantly dashing about, and lashing the red blood corpuscles into motion with their flagellum. They swim equally well with either extremity in front. These organisms multiply in the blood by simple longitudinal division, and often become so numerous as to number several millions in every drop of blood. They are sucked, along with the blood, into the stomach of the fly, live and multiply in the alimentary tract for several days, and, when the fly has its next feed on an animal, take the opportunity of gaining access to the blood of the new host, and so set up the disease.

Let me now throw on the screen a representation of the tsetse-fly (*Glossina morsitans*) which does all the mischief. Experiments were made which showed that the fly could convey the parasite from affected to healthy animals for at least forty-eight hours. It is a curious fact that among all the blood-sucking flies the tsetse-fly alone has this power, and up to the present the cause of this has not been thoroughly cleared up. Lately, however, evidence has been brought forward to show that an enormous multiplication and development of the trypanosomes take place in the fly's intestine, a few trypanosomes multiplying to masses containing numberless parasites within twenty-four hours. Now, if this multiplication only takes place in the intestine of the tsetse-fly, and not in the other kinds of biting flies, this would probably account for the curious connection between the tsetse-fly and the disease. This multiplication of the trypanosomes in the tsetse-fly was discovered by Gray and Tulloch, two young army medical officers, while working in Uganda on "Sleeping Sickness" during the present year.

Not only was it found that the tsetse-flies could convey the disease from sick to healthy animals, but it was also proved that the wild tsetse-flies brought from the "Fly Country" and straightway placed on healthy animals also gave rise to the disease. The question then arose as to where the tsetse-flies living in the "Fly Country" came by the trypanosomes. There were no sick horses or cattle in the "Fly Country." Investigation brought to light the curious fact that most of the wild animals—the buffalo, the koodoo, the wildebeeste—carried the trypanosomes in small numbers in their blood, and it was from them that the fly obtained the parasite. The wild animals act as a reservoir of the disease. The trypanosome seems to live in the blood of the wild animals without doing them any harm, just as the rat trypanosome lives in the blood of healthy rats; but when introduced into the blood of such domestic animals as the horse, the dog, or ox it gives rise to a rapidly fatal disease. The discovery that the wild animals act as a reservoir of the disease accounted for the curious fact that Tsetse-fly Disease disappears from a tract of country as soon as the wild animals are killed off or driven away.

In 1895 the living trypanosome which causes the Tsetse-fly Disease was sent to England in the blood of living dogs, in order that it might be studied in the English laboratories. These trypanosomes have been kept alive ever since by passage from animal to animal, and have been sent all over Europe and America, so that our knowledge of this kind of blood parasite has rapidly grown.

Koch, in a recent address, says that our knowledge of protozoal diseases is based on three great discoveries—that of the malarial parasite, by Laveran; of the *Piroplasma bigeminum*, the cause of Texas Fever or Redwater in cattle, by Smith; and, lastly, this discovery of a trypanosome in Tsetse-fly Disease.

We may therefore, think, congratulate ourselves on the growth of our knowledge of this great stock disease during the last ten years.

Since 1895 many other trypanosome diseases have been discovered in all parts of the world. The latest and most important of these is one which affects human beings, and is known as "Sleeping Sickness." This "Sleeping Sickness," which occurs on the West Coast of Africa, particularly in the basin of the Congo, has within the last few years spread eastward into Uganda, has already swept off some hundreds of thousands of victims, is spreading down the Nile, has spread all round the shores of Lake Victoria, and is still spreading southward round Lakes Albert and Albert Edward. This disease is in all respects similar to the Nagana or Tsetse-fly Disease of South Africa, except that it is caused by another species of trypanosome and carried from the sick to the healthy by means of another species of tsetse-fly—viz. the *Glossina palpalis*.

I now throw on the screen a map of Africa, showing, so far as is known up to the present, the various fly districts, and you will see from this map that it is not at all improbable that this human Tsetse-fly Disease may spread southward through the various fly districts to the Zambesi, and may even penetrate as far as the fly districts of the Transvaal and Zululand.

I am sorry to say that, in spite of innumerable experiments directed towards the discovery of some method of vaccination or inoculation against these trypanosome diseases, nothing definite, up to the present time, has been discovered. At present there does not seem to be any likelihood that a serum can be prepared which will render animals immune to the Tsetse-fly Disease. In the same way it has also been found impossible, up to the present, to so modify the virulence of the trypanosome as to give rise to a modified, non-fatal form of the disease. Again, all attempts at discovering a medicine or drug which will have the power of killing off the parasites within the animal organism, without at the same time killing the animal itself, have not as yet been successful, although some drugs, such as arsenic and certain aniline dyes (Ehrlich), have a very marked effect in prolonging the life of the animal. As this disease is fatal to almost every domestic animal it attacks, it seems very improbable that there is much chance of cultivating an immune race of horses, dogs, or cattle which will be able to withstand the action of the parasite. It is quite evident that if an acquired immunity of this kind could be brought about, such a race of immune animals would now be found; but, as a matter of fact, there are no horses, dogs, or cattle in the "Fly Country." In other protozoal diseases, such as the Piroplasmata, this acquired immunity seems to come about fairly readily.

To sum up, then, the increase in our knowledge of Tsetse-fly Disease during the last ten years, we may say that we have discovered the cause in the shape of the small blood parasite Trypanosoma; we have found that the reservoir of the disease exists in the wild animals, and that we can blot out this disease from any particular tract of country by the simple expedient of destroying or driving away the wild animals. We still have no means of preventive inoculation or successful medicinal treatment in this disease.

(2) *Trypanosomiasis of Cattle.*

This disease seems to be widespread over all South Africa. It cannot be said to be of much practical importance, as the cattle infected do not seem to be seriously affected by it. It is caused by a species of trypanosome remarkable for its large size, which was discovered by Dr. Theiler some years ago, and named *T. theileri.*

Dr. Theiler states that it is conveyed from animal to animal by the common horse-fly, *Hippabosca rufipes.*

This, then, is a short account of the trypanosome diseases which affect South Africa.

Of late years the Tsetse-fly Disease has become of less practical importance to the Transvaal, from which it has practically disappeared. This is due to the disappearance of the game, killed off by Rinderpest; but with the preservation and restoration of the reserves with big game the disease is certain to reappear. Why the fly should disappear with the game is not known.

B. Parasite unknown.

I. *Rinderpest.*

We now turn our attention to the important diseases of the second group. In these the parasites causing them are unknown—that is to say, no parasites can be detected by the microscope or by culture—but it is equally true that they must be present in the blood and fluids of the sick animals in some form or other. In all probability they are ultra-microscopic—too small to be seen with our present instruments. This is borne out by the fact that they are able to pass through the pores of porcelain filters, which keep back the smallest micro-organisms we are able to recognise.

The first of the second group of diseases is Rinderpest, which has overrun and devastated South Africa within the last ten years.

Rinderpest has been known from time immemorial in Europe and Central Asia, and is an exceedingly fatal disease, killing 90 to 100 per cent. of the cattle attacked.

The recent epidemic, according to some, originated in the Nile provinces, and slowly crept southwards, reaching the Transvaal in 1896, after a journey lasting some fifteen years. Great efforts were made to oppose its passage, but nothing seemed to avail. In parts of the country where there were few or no cattle the epidemic spread by means of the wild animals—particularly the buffalo—which have been exterminated in many places.

Ten years ago the symptoms and contagious nature of this disease were well known, but nothing was known as to methods of prevention, and it is to the investigation of this epidemic in South Africa that the discovery of practical methods of immunising cattle, and in this way of stamping out the disease, is due.

As soon as it was apparent that the epidemic was spreading into South Africa, all the Colonies made strenuous efforts to combat it. The Transvaal Government invoked the aid of the Pasteur Institute, and Messrs. Bordet and Danysz were sent out to discover some method of prevention. They worked near Pretoria, and were assisted by Dr. Theiler, then the Principal Veterinary Surgeon. Before they arrived on the scene the Natal Government had dispatched Mr. Watkins-Pitchford, their Principal Veterinary Surgeon, to the Transvaal, where he also at first had Dr. Theiler as his colleague, and where he did some good pioneer work in the serum therapeutics of the disease. In the Cape Colony Dr. Hutcheon, the Principal Veterinary Surgeon, and Dr. Edington, the Government bacteriologist, were no less active. It is, however, to Prof. Robert Koch, of Berlin, that the honour is undoubtedly due of first publishing a practical method of immunising cattle against Rinderpest. He arrived at Kimberley on December 5, 1896, and in the incredibly short space of time of two months was able to report two methods of immunising, viz. by the injection of Rinderpest bile, and, secondly, by the injection of serum from immune animals. I have always thought that the discovery that the injection of bile taken from an animal dead of Rinderpest rendered cattle immune was particularly brilliant. Up to that time no one had dreamt that bile could possess such a quality. It is true that both Transvaal and Orange Free State Boers are said to have used a mixture of bile and blood from dead animals before Koch's researches, and also that Semmer in 1893 showed that serum might be used for protective purposes; but still to Koch is due the credit of making these processes practical. After he left South Africa his work was continued by Kolle and Turner, who greatly improved the methods; and it is to them, and to the other workers mentioned above, that we owe the fact that Rinderpest has now lost its terrors.

In the last recrudescence of this disease in the Transvaal, in 1904, Mr. Stewart Stockman, the Principal Veterinary Surgeon, and Dr. Theiler, thanks to the experience and knowledge gained during the last ten years, were enabled to stamp out the disease rapidly and completely. It is to them also that we owe our knowledge of the dangers of the intensive method of inoculation, much used in the past and due to Kolle and Turner, and the introduction of the fighting against the plague by the inoculation of the healthy cattle by injections of immune serum alone.

In the Tsetse-fly Disease our advance in knowledge has been in regard to the causation of the disease, and not in its prevention; it is quite otherwise with Rinderpest. The contagion or cause of Rinderpest is absolutely unknown. We know it exists in the blood, nasal, mucous, and other secretions of the sick animal, as all these are infective, but no one has seen it. The smallest quantity of blood will give the disease if injected under the skin of a healthy animal. We also know that the contagium is not very resistant. Blood soon loses its virulence after it leaves the body, and the effect of drying or the addition of chemical preservatives, such as glycerin, act also injuriously to the contagium, whatever it may be. It evidently belongs to the ultra-visible sort of micro-organisms, as it is said to pass through a porcelain filter.

How the contagium passes from the sick to the healthy is assumed to be by contact. No experiments have, so far as I am aware, been made as to whether it is conveyed by insects as well; but, as Prof. John MacFadyean says, as it spreads in all countries and climates and seasons, and the contagium is easily carried on the persons or clothes of human beings, it is improbable that insects have anything to do with it.

It is in the methods of protective inoculation that the great advance has been made in our knowledge of this disease. Ten years ago no means were available to stay the progress of this plague; now it has lost its terrors. As soon as it appears it can be immediately attacked and stamped out. This is done by rendering the surrounding cattle immune to the disease by injecting immune serum. This serum is prepared by taking immune cattle and hyper-immunising them by the injection of large quantities of virulent blood, so as to make their blood serum as antitoxic as possible. If there are no immune cattle at hand, cattle can be immunised by Koch's bile injection method and then hyper-immunised; but, of course, in practice—for example, here in the Transvaal—large quantities of immune serum are kept ready for emergencies, and a herd of immune cattle kept up for the supply of the serum. This satisfactory state of affairs, so far as this disease is concerned, is, of course, the outcome of an immense amount of thought and experiment, and I have already mentioned the chief scientific men to whom this country owes this great boon.

Different methods of immunising have been tried during these years. Up to 1903 the prevailing custom was to use what was known as the virulent-blood and serum method. That is to say, immune serum and virulent blood were injected at the same time, in order that the animal might pass through a modified attack of the disease. Since 1903, however, in the Transvaal this method has been stopped, and the "serum alone" method introduced. This method is based on the fact that the virus of Rinderpest does not retain its infective property outside the body for more than a day or two; that it dies out in the animal, as a rule, in fourteen days, but in chronic cases only after thirty days, and that therefore the healthy cattle in an affected herd must be protected for this length of time. Now "serum alone only protects for about ten days, and therefore the cattle must be inoculated three times at intervals of ten days. The doses of serum must also be large—from 50 c.c. to 200 c.c.—so that this method of stamping out Rinderpest, although quite efficacious, entails a good deal of labour. It is necessary, then, to spare no expense in making the Veterinary Department efficient, and any cheese-paring legislation in this direction may be disastrous.

II. *Horse-sickness.*

The next stock plague I would bring before your notice is Horse-sickness. This is a disease which only affects equines—the horse, mule, and rarely the donkey. It is a very fatal disease, carrying off thousands of horses every year. It is one of the most important diseases in South Africa, and, if it could be coped with, would enable the Transvaal to become one of the best horse-breeding countries in the world. At present it is dangerous for anyone in Natal and many parts of the Transvaal to possess a valuable horse, the chances of losing it by Horse-sickness being so great.

In 1895, when I went to the north of Zululand with the Ingwavuma Expedition, we lost all our horses with this disease. We started with a hundred horses, and had to march back on foot, every horse having died.

Ten years ago, when I arrived in South Africa, our knowledge of this disease was confined to the disease itself; nothing was known as to its causation or prevention. Credit is due to Dr. Edington for having accurately described the lesions and shown its ready inoculability, period of incubation, &c. He, however, fell into the mistake of attributing its causation to a species of mould fungus.

Etiology: Geographical Distribution.—Horse-sickness is widely distributed throughout Africa. It is common in Natal, Zululand, the greater part of the Transvaal, Rhodesia, Bechuanaland, and Portuguese East Africa. In Cape Colony it occurs in epidemics, with intervals of ten to twenty years. It is undoubtedly a disease which prevails chiefly *in low-lying localities* and valleys, and is but rarely met with in elevated exposed positions. It, however, is met with now and then in river valleys up to an elevation of some thousands of feet. *Season* has also a remarkable influence on its development, being exceedingly common in summer and disappearing on the appearance of the first frosts of winter.

Ten years ago various theories were held as to the cause of this disease. Some people thought that it was due to eating poisonous herbs; others, to some peculiarity or state of the night atmosphere; others, to eating grass covered with dew; and still others, to the eating of the spiders' webs which may be seen on the grass in the morning. It was known at that time not to be contagious in the ordinary sense of that term; that is to say, a horse could be stabled alongside a case of Horse-sickness without incurring the disease, or a horse might be placed without danger in the same stall in which a horse had recently died of Horse-sickness.

Nature of the Disease.—A horse which has been exposed to infection shows no signs of the disease for about a week. Its temperature then goes up rapidly, and it dies after four or five days' illness. Very often the horse appears perfectly well until within a few hours of death. For example, my horse was the last one to die on the Ingwavuma Expedition. On the day of his death I rode him until noon without noticing anything amiss. He then became rather dull in his movements, and I handed him over to the groom to lead. He died that evening immediately after we got into camp. It is, therefore, a very rapidly fatal disease, and almost every horse which is attacked by it succumbs. I have never seen a case of Horse-sickness which had been brought on by artificial inoculation recover. But there can be no doubt that a small percentage of horses infected naturally do recover, and these recovered horses are, more or less, immune in future to the disease. There is no necessity for me to describe the symptoms of this well-known disease, as everyone who has to do with horses in South Africa is perfectly familiar with it, and everyone has seen dead horses with the characteristic mass of white foam issuing from their nostrils, due to the effusion of the liquid part of the blood into the lungs and trachea.

Nature of the Virus which causes this Disease.—There can be no doubt that this disease, like the Tsetse-fly Disease, is caused by some form of blood parasite. A small quantity of fluid taken from any part of a horse suffering from Horse-sickness is capable of giving rise to the disease if injected under the skin of a healthy horse. For example: the thousandth part of a drop of blood from a sick horse will, in many cases, give rise to the disease if injected under the skin of a healthy horse. It must be admitted, however, that some horses require a larger dose than others, but it may be said that no horse has yet been found to withstand more than a comparatively small quantity of infective blood thrown under the skin. Now, although every drop of blood must contain many of the organisms of this disease, yet the most careful examination of such blood under the highest powers of the microscope reveals nothing. Again, if we filter Horse-sickness blood through a porcelain filter—a filter which is capable of keeping back all the known visible micro-organisms—the filtrate is found to be virulent. It is evident, then, that we are here dealing with a blood parasite so small in size as to be absolutely invisible to the highest powers of the microscope, and also so minute as to readily pass through the pores of a Chamberland filter. What the nature of this parasite is one cannot tell. It behaves in many curious ways. For example, Horse-sickness blood which is simply dried and pounded into powder is found to be perfectly inert. On the other hand, blood kept in the moist condition remains virulent and capable of giving rise to the disease for years. Or, again, the germ of Horse-sickness is so resistant to external agencies that if, as described by MacFadyean, a part of the liver of a horse dead from Horse-sickness be buried in the ground and subjected to putrefaction, it is found that the liver tissue retains its infectivity for months. Although a very small quantity of blood introduced under the skin of a horse will almost certainly give rise to the disease, it is quite different if the blood is introduced into the stomach. In the latter case a small quantity of blood has no effect, and the horse requires to be drenched with a pint or more before the disease can be given in this way.

The question now arises as to how horses are infected by this disease in Nature. On account of the small quantity of blood which will give rise to the disease if injected under the skin, and the large quantity required before the disease can be conveyed through the stomach, for a long time it has been supposed that it must be conveyed from sick to healthy horses by means of some biting insect. Experiments have been made within the last few years by Watkins-Pitchford and others in order to clear up this aspect of the question. Horses have been placed in fly-proof shelters in exceedingly unhealthy places, and it was found that in no case did any of these protected horses incur the disease; whereas horses allowed to feed in the same place, but without any shelter, soon succumbed to the disease. But, up to the present, so far as I am aware, the particular biting fly, mosquito, or other insect which is the carrier of this disease has not been discovered, and there can be no doubt that one of the most important facts to make out in the etiology of this disease is the discovery of the particular insect which conveys the disease from the sick to the healthy. By this discovery a flood of light may be thrown on the causation of the disease, and some means discovered of combating the disease through the insect, as has been successful in some instances in regard to the case of human malaria.

Prof. MacFadyean also suggests that experiments are needed to show what is the "reservoir" of the virus.

Prevention.—Although we have been unfortunate up to the present in not being able to make out the exact nature of the parasitic cause of this disease, or to discover the exact insect which carries it, a large amount of patient persevering work has been done within the last ten years in regard to its prevention by protective inoculation.

In this important work Bordet, Edington, Koch, Theiler, Watkins-Pitchford and others have laboured for many years, and, according to recent reports, with some measure of success.

Dr. Edington, for example, who has been working at this problem for several years, reports that Heart-water is identical with Horse-sickness, and that by inoculating mules with Heart-water blood he has been able to salt them against Horse-sickness. He says that experiments testing this vaccine show it to be an ideal one. It gives a high protection to the animals inoculated. Its keeping powers are excellent. No animal has died as the result of this inoculation nor has any dangerous symptom been produced. He states that he is not in a position to supply a vaccine for Horse-sickness in horses, but has every hope of attaining this successful end very shortly.

We must congratulate Dr. Edington on his results, and trust that this method of conferring immunity may prove itself to be successful when put to practical use. For my part, I am somewhat sceptical of Dr. Edington's methods of immunising against Horse-sickness. I am sure he will forgive my expression of scepticism when I recall to his memory the various methods he has already brought forward, just as optimistically, which have all been tried and found wanting.

Dr. Koch has lately recommended a method of immunisation against Horse-sickness. This is the artificial establishment of an active immunity in susceptible animals by gradually increased doses of virulent blood, alternated in the early stages of treatment with the injection of serum prepared from the blood of highly fortified salted horses. Mr. Gray reports that the experiments already conducted on these lines show that the process as laid down by Koch requires important modification before the process of establishing immunity against Horse-sickness can be of any practical use.

Mr. Watkins-Pitchford in Natal is also hopeful of succeeding in producing immunity against Horse-sickness.

Dr. Theiler, too, reports that he has succeeded in producing a serum which can be utilised in connection with virulent blood to confer active immunity. He informs me that his method is a subcutaneous injection of serum and an intra-jugular injection of virus carried out simultaneously. The death rate in mules, from the effect of the inoculation, he states to be about 5 per cent. It is higher in horses, but he expects shortly to attain the same result in them. During the last Horse-sickness season he exposed 200 immunised mules to natural infection in various parts of the country. Of that number only one died with symptoms of Horse-sickness. As Dr. Theiler is himself communicating his method in detail to the Association, I need not enter more fully into it.

The man who discovers a practical method of dealing with Horse-sickness will be one of the greatest benefactors of this country. There has always been a tradition that a large money reward is awaiting this discovery. I do not know whether this is well founded or not, but certainly such a work would well deserve the highest possible reward. The best reward is to give the successful investigator more opportunity and more assistance in pursuing his beneficent work. The reward given by the French people to Pasteur was the Pasteur Institute; by the German Government to Koch, the Imperial Hygienic Institution.

Catarrhal Fever of Sheep: Blue Tongue.

This disease was first described by Hutcheon, the Chief Veterinary Surgeon of Cape Colony.[1] It is very similar in many respects to Horse-sickness. Both these diseases occur most often in low-lying, damp situations, such as river valleys and the coast plain. They also occur at the same time of the year; that is, from January to April. Blue Tongue, like Horse-sickness, is probably carried from the sick to the healthy by means of some night-feeding insect. At the same time the diseases are not identical, since the inoculation of Horse-sickness blood into a sheep does not give rise to Blue Tongue, nor the blood of the sheep injected into the horse give rise to Horse-sickness.

To Mr. Spreuill, Government Veterinary Surgeon in

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[1] It is to Mr. Hutcheon that South Africa owes its knowledge of many stock diseases. For the last twenty-five years he has laboured with the utmost earnestness in Cape Colony, often under trying conditions, and his description of the various diseases formed the basis of all the modern work done on the subject.

Cape Colony, acting under the advice of Hutcheon, is due the credit of proving that a preventive serum could be prepared capable of immunising sheep against this disease. Dr. Theiler informs me he has repeated Mr. Spreuill's experiments, and they hope to introduce this method of inoculation at an early date.

Heart-water of Cattle, Goats, and Sheep.

This disease was also first clearly described by Mr. Hutcheon. It occurs in the Transvaal, Natal, and Cape Colony, and is responsible for much of the yearly loss among the cattle, sheep, and goats.

Like the last disease—Blue Tongue—it resembles Horse-sickness in many ways, and, in fact, has been described by Dr. Edington as being identical with it. Like Horse-sickness, it is a blood disease with an invisible parasite, so that blood injected under the skin of susceptible animals gives rise to the disease. One difference between the parasites of the two diseases is, that whereas that of Horse-sickness is contained in the fluid of the blood, that of Heart-water is probably restricted to the red blood corpuscles. The serum separated from the blood is incapable of giving rise to the disease, and the straw-coloured pericardial fluid, when injected into susceptible animals, fails to give rise to any symptoms of the disease. Horse-sickness blood filtered through a porcelain filter is still infective; the opposite holds good up to the present with Heart-water. Horse-sickness blood can be kept for years without losing its virulence; Heart-water blood loses it in forty-eight hours.

Heart-water has a peculiar distribution, being restricted to the certain tracts of country with a warm, moist climate. It is known to farmers that if they remove their flocks to the high veld the disease dies out.

To Lounsbury is due the credit of explaining these facts. He found that the disease is carried from sick to healthy animals by means of the bont tick, *Amblyomma hebraeum.* This tick leaves its host between each moulting, and a larva which sucks the blood of an infected animal is capable of giving rise to the disease in a susceptible animal either as a nympha or imago. The distribution of this tick corresponds to the distribution of the disease. If this tick could be killed off, the disease would disappear from the country. This could doubtless be done on individual farms by long-continued dipping; but in the meantime some method of immunisation might be devised.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

The next session at the South-Eastern Agricultural College, Wye, will commence on Monday, October 2, when an address will be given by Prof. Marshall Ward, F.R.S.

The new session of King's College will be opened on October 3, when an address will be delivered by Prof. Clifford Allbutt, F.R.S., on "Medical Education in London." On October 4 an inaugural lecture will be given by Prof. Arthur Dendy on "The Study of Zoology."

The inquiry into the general conditions of the home life of the Berlin brass-workers, their education and trade conditions, which the small party of Birmingham delegates carried out last April, is embodied in an interesting and entertaining manner in a report recently issued—"The Brass-workers of Berlin and of Birmingham," by Messrs. R. H. Best, W. J. Davies, and C. Perks (P. S. King and Son, price 1*s*.). The sensible inferences and criticisms contained in the report are ample evidences of close and accurate observation. The net practical conclusion of the inquiry seems to be that so long as the Birmingham brass-worker confines himself to the reproduction of a number of plain models, his work, especially his polished brass-work, is excellent, both in price and in finish; but "the Berlin training schools have produced a class of artisans with artistic talent, who find ready employment and are of great assistance to the employers. . . . A proper apprenticeship to his trade has fitted him (the Berlin brass-worker) and placed him in a position to supply the internal construction of intricate work without every minute detail being put down for him on paper. In the bronzing and treatment of the finish a greater freedom is apparent and a greater variety and novelty"; in fact, "they lead the way, we follow. . . ." The moral is obvious; indeed, in the further discussion of this point we find what is undoubtedly the most generally applicable and valuable criticism in the whole report:—"It is on the intellectual side that Birmingham requires to adapt itself to changed conditions: not to cheapening its wares but to getting more conception into them."

SOCIETIES AND ACADEMIES.

London.

Royal Society, April 13.—"The Amplitude of the Minimum Audible Impulsive Sound." By Dr. P. E. **Shaw.**

In a previous paper (*Phil. Mag.*, December, 1900) the author found this quantity by direct measurement, and Rayleigh, Franke, Toepler, and Boltzmann have investigated the minimum audible for continuous sound. In each of the above researches the micrometer was not sensitive enough actually to measure the least audible amplitude; the relation of current to amplitude was determined for relatively large amplitudes, and separate measurements were made of the current which gives the least audible sound. Extrapolation then gives the amplitude in question.

The present paper shows how the amplitude can be measured directly without extrapolation; it is even possible, as shown in the tables, to measure movements the amplitude of which is too small to be audible. The instrument is the improved electric micrometer described at the Royal Society (see p. 495), which is capable of showing a movement of 0·4 $\mu\mu$.

There are two distinct parts in the determination:—

(1) Observe the position of the diaphragm of a telephone when at rest, by making electric contact; draw away the measuring point of the micrometer and pass a steady current through the telephone so as to move the diaphragm to a new position of rest. Now move up the measuring point to the diaphragm, watching the micrometer screw and listening to the contact. Thus measure the movement of the diaphragm due to a set of steady currents down to such small ones as cause imperceptible motion. Plot the relation between movement and current.

(2) Apply the ear to the telephone and pass through it the same set of currents as before. For each current, except the smallest, a sound is heard when the current is stopped. We thus learn the relation of current to audibility.

The curve above at once gives the relation of amplitude to audibility. The sound is impulsive, for the diaphragm is released from a position of strain, vibrates under great damping, and soon comes to rest.

Both right and left ear of the author were used. He found, averaging results, 0·7 $\mu\mu$ as result for the right ear, and 0·9 $\mu\mu$ for the left.

The fundamental of the diaphragm when clamped hard to the case was found by testing it against tuning forks to have frequency about 580.

The following table of amplitudes is given:—

	A	B
Just audible	0·7 $\mu\mu$	0·14 $\mu\mu$
Just comfortably loud	50 $\mu\mu$	10 $\mu\mu$
Just uncomfortably loud .	1000 $\mu\mu$	200 $\mu\mu$
Just overpowering ...	5000 $\mu\mu$ ...	1000 $\mu\mu$

The word "just" here implies in each case the lower limit. The amplitude of the diaphragm must not be confused with that of the air which it vibrates. Lord Rayleigh obtained the relation between these amplitudes to be roughly 5 to 1.

Column A gives numbers actually found in the telephone, and using Rayleigh's factor we obtain column B for the corresponding amplitude of the air.

It should be observed that 0·14 $\mu\mu$ is the smallest audible amplitude for an expectant ear when the conditions as to silence are exceptionally favourable; yet 10 $\mu\mu$ is the amplitude for the smallest audible sound in air, about which the ear can be quite sure when the conditions are normally favourable, and the ear not listening for the sound.

From the results found the author calculates the ampli-